DECOLORIZATION OF AGRO-INDUSTRIAL WASTEWATERS USING ELECTROCOAGULATION

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ABSTRACT
Greece, although not over-industrialized, is facing issues connected to pollution of its water resources, as conventional wastewater treatment methods often prove ineffective in terms of removing pollutants, such as pigments. Therefore, the need of developing efficient, modern anti-pollution techniques for the preservation of a viable environment is urgent as ever. Electrocoagulation (EC) is one of these widely studied, promising methods. In this study EC is investigated as an alternative method for the decolorization of table olive processing wastewaters (TOPWs) and real printing ink wastewater (PIW). In all experiments, complete decolorization of two types of agro-industrial wastewater was achieved. According to the experimental data, aluminum electrodes were more efficient in reducing color than iron electrodes. Concluding, EC can be a viable and realistic choice for agro-industrial wastewater decolorization.

INTRODUCTION
Pollution caused by untreated wastewater disposal is a serious environmental issue. Various countries have legislated specific directions for the treatment and final disposal of this agro-industrial wastewater [1].

Printing ink wastewater (PIW) is generated from the industrial equipment cleaning process in various printing enterprises, such as, textile, plastics and cardboard packaging industries [2]. Printing ink wastewater contains non-biodegradable compounds, trace amounts of metals pigments and adhesives [3]. Therefore, PIW must be treated prior to discharge to prevent serious environmental problems including water quality degradation and toxicity effects on aquatic organisms and plant growth.

Olive trees have been cultivated for their fruit for many centuries, especially in Mediterranean countries. Apart from the extraction of high-valued olive oil, olive fruit are also exploited at industrial scale to produce edible table olives [1].TOPWs contain high levels of inorganic and organic substances, the latter also comprising phenolic compounds extracted from the fruit during the preservation process. TOPW is usually dark brown in color and has a characteristic odor that can be described as rather acidic, similar to that of olive oil [4].

The aforementioned physicochemical characteristics make PIW and TOPW difficult to treat using conventional biological methods. Advanced oxidation processes and electrochemical techniques have been usually proposed for the treatment, disposal and reuse of these types of intensively colored wastewaters [5].

Electrocoagulation (EC) is another alternative technology that could possibly solve the depollution problem [6]. This treatment method is based on the destabilization of the colloidal particles existing in the effluent's bulk volume and their consequent removal through coagulation and precipitation [7]. The use of EC as a treatment technology has several advantages over standard biological systems and AOPs including: simple apparatus operation, short processing times, no additional chemical requirements, and colorless and odorless effluents [8].

Aluminum and iron are the most commonly tested electrode materials used for EC. Their availability, low cost, and high valence are considerable advantages making them favorable choices compared to other metal materials [7].

RESERCH GOALS AND METHODOLOGY

The present study investigates the decolorization of real PIW derived from a printed corrugated box manufacturing plant (dark color) and real TOPW originating from black Kalamon variety olives (dark brown in color) by EC process.

The PIW was collected from a receiving tank contained homogenized wastewater of a local corrugated board packaging factory located in southern-central Greece and the TOPW was obtained from a packaging factory located in Aitoloakarnania (western Greece) (see Table 1).

Conductivity and pH measurements were carried out run using a HANNA HI 5521 multiparameter instrument. COD was determined by the closed reflux dichromate method according to the Standard Methods [8] using a Wastewater Treatment Photometer (HANNA HI 83214). The extent of PIW and TOPW decolorization after EC treatment was assessed by measuring the absorbance at 565 nm and 400 nm, respectively, which was obtained by scanning the samples in the 400-700 nm wavelength band. The spectrophotometer used to determine color absorbance was provided by LANGE HACH (model DR 5000). The equation used to determine decolorization efficiency in each experimental run was:

$$R\,\% = \frac{C_0 - C}{C} \times 100 \qquad (1)$$

where, R(%): removal rate; C_0: initial color absorbance; C: final color absorbance.

During all experiments, the pH was not adjusted and electrolytes (e.g., NaCl) were not added to the system. Finally, all the experiments were conducted in triplicate with a relative standard deviation not exceeding 5%.

EXPERIMENTAL PART

Experiments were conducted under batch operation mode. Reactor volume was 600 cm^3 and a magnetic stirrer was used to maintain homogenization in the wastewater's bulk volume. The temperature inside the electrolytic cell was 27-30°C and kept constant using a cooling jacket (Figure 1). The two plate electrodes used (placed in the middle of the reactor) were either both aluminum (Al) or both iron (Fe). The active surface of the anode electrode (as well as cathode) was kept constant at 12 cm^2. Inter-electrode distance was also kept constant at 0.3 cm. According to the literature, the minimum distance between the anode and cathode limits the Ohmic drop between the two [6]. The electrodes were connected in monopolar parallel mode to a DC regulated power supply (model QJ3005C) that provided the desired current and voltage to the system (Figure 1).

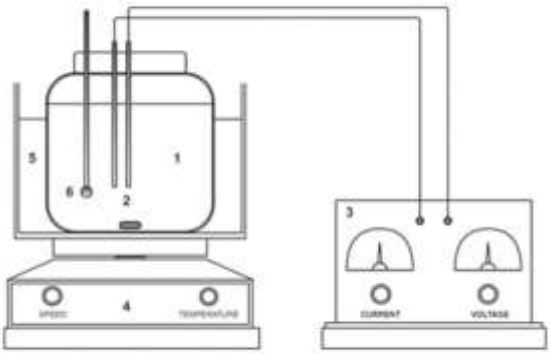

Figure 1. *Batch reactor and experimental set-up: 1. Electrolytic cell, 2. Electrodes (anode, cathode), 3. DC power supply, 4. Magnetic stirrer, 5. Water bath, 6. Thermometer.*

The basic physicochemical characteristics of the PIW and TOPW tested are presented in Table 1. In this study, the experiments were conducted using wastewaters diluted with tap water.

Table 1. *Physicochemical characterization of the PIW and TOPW used in the experiments. Data are presented as mean ± SD values from three separate measurements.*

Physicochemical characteristics	PIW	TOPW
COD (mg L^{-1})	2,500 ± 100	3,000 ± 150
Conductivity (mS cm^{-1})	1.7 ± 0.1	10,000 ± 1,000
pH	7.0 ±0.2	5.5 ± 0.2
Color	Black	Dark brown

RESULTS AND DISCUSSION

EC was evaluated as a decolorization method for PIW and TOPW. The initial COD concentration of PIW and TOPW was 2,500 mg L^{-1} and 3,000 mg L^{-1}, respectively. Color removal was measured at 83.33 mA cm^{-2} current density using Al and Fe electrodes (Figures 2 and 3). Al and Fe are commonly chosen as electrode materials for the treatment of agro-industrial wastewater due to their low price and high availability in comparison with other materials.

Figure 2 shows that the percentage of color removal obtained reached about 99% in the first 20 min, for both the Al and Fe electrodes. Similar high color removal efficiencies were also observed by Thuy et al., [10]. However, in the case of the Fe electrode, the treated wastewater appears a yellowish color therefore, aluminum electrodes proved more efficient than iron electrodes at removing color.

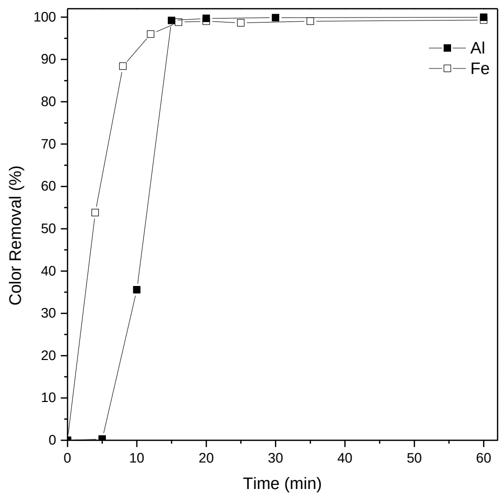

Figure 2. *Color removal of PIW versus time using different electrode materials (Al, Fe) and 83.3 mA cm^{-2} current density.*

The effect of electrode material on the decolorization of TOPW using EC was also investigated. Experimental results for the effluent with initial COD of 3,000 mg L^{-1} (Figure 3) indicated that it is possible to completely remove the effluent's color, regardless of the electrode material used. Complete decolorization of TOWP effluents is feasible using EC, as in all experimental runs color removal percentages of over 90% were achieved. It was observed that both aluminum and iron electrodes produced maximum color removal in the first 30 min of the process (Figure 3). Nevertheless, Al electrodes gave more stable, clear-colored effluents than Fe electrodes. It is worth noting that García-García et al., [11] also observed the same phenomenon in color removal when applying aluminum and iron electrodes to treat TOPW.

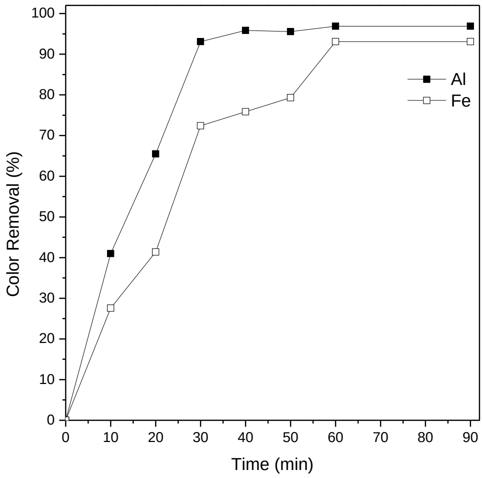

Figure 3. *Color removal of TOPW versus time using different electrode materials (Al, Fe) and 83.3 mA cm^{-2} current density.*

CONCLUSIONS

The influences of electrode material on the performance of EC to decolorized PIW and TOPW were investigated. From the experimental results it can be deduced that:

- Aluminum appears to be the more suitable electrode material both in terms of effluent decolorization.
- EC could be effectively applied for the complete decolorization of PIW and TOPW.

ACKNOWLEDGEMENTS

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